

**FINAL REPORT TO THE AFOSR**  
**STUDIES IN SCANNING PROBE MICROSCOPY**  
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Dror Sarid

*Optical Sciences Center, University of Arizona, Tucson, Arizona 85721*  
*Arizona Research Laboratories, University of Arizona, Tucson, Arizona 85721*

**Abstract**

The following is a final report on our work in the field of Scanning Probe Microscopy (SPM), which has been funded by the AFOSR under Contract #F49620-92-J-0164. The AFOSR funding was instrumental in the establishment of a multi-lab facility at the Optical Sciences Center, which performs research in SPM using two ultrahigh vacuum (UHV) STM facilities, and several Atomic Force Microscopy (AFM) facilities. The fabrication and characterization work performed in the SPM Laboratory is supplemented by infrared (IR) spectroscopy, high resolution transmission electron microscopy (HRTEM), and scanning electron microscopy (SEM), available in other departments on campus. The report covers the following areas: (1) GaAs and CdSe Structures, (2) Optical Interactions on a nm and nsec Scales, (3) Fullerenes on Gold, (4) Fullerenes on  $MoS_2$ , (5) Fullerenes on Si, (6) SiC, (7) Nanotubes, (8) Scanning Force Microscopy, and (9) Biology. The results of the three-year research appeared in 30 papers and a book titled *Scanning Force Microscopy, With Applications to Electric, Magnetic, and Atomic Forces* (Oxford University Press, Revised Edition, 1994).

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# 1 Research highlights

## 1.1 GaAs and CdSe Structures

STM and AFM were used to characterize oxidation effects on cleaved multiple quantum well surfaces in air, and growth of Wurtzite CdSe thin films with extremely narrow excitonic luminescence [1, 2]

## 1.2 Optical Interactions on a nm and nsec Scales

The STM was used to fabricate gold nanostructures, and map the photon emitted from these structures. It was demonstrated that the STM can be operated on a nsec time scale using, for example, the beat of the longitudinal modes of a HeNe laser at the tip-semiconductor junction. We are currently developing a similar method that employs fast laser diodes, and plan on characterizing the lifetime of charge carriers, on and around nanostructures, with nm and nsec resolutions. [3, 4, 5, 6]

## 1.3 Fullerenes on Gold

Fullerene molecules, deposited on gold substrates were characterized by STM and AFM. In particular, the origins of intermolecular contrast have been explored and explained. A review of the field discusses the various issues associated with the adsorption of the fullerenes on metal surfaces [7, 8, 9, 10, 11, 12].

## 1.4 Fullerenes on $MoS_2$

The adsorption of fullerenes on the layered-structure semiconductor  $MoS_2$  is of interest because of the van der Waals type interactions at its cleaved surface. The interactions of fullerenes with the surface have been characterized under UHV conditions. [13]

## 1.5 Fullerenes on Si

The first system investigated consisted of fullerenes adsorbed under UHV conditions on clean Si(111) and Si(100) reconstructed surfaces, as a function of fullerene layer thickness, temperature of deposition and annealing, and a combination of deposition of fullerenes and additional Si atoms [14, 15, 16, 17, 18, 19].

## 1.6 SiC

It was found that by holding a Si substrate at an elevated temperature while bombarding it with fullerenes, one can grow SiC films. IR and HRTEM were used to verify that the films indeed consisted of SiC. We are currently looking for methods to optimize this novel method that utilizes fullerenes as the carbon source. We exploited the fact that fullerenes do not adsorb on SiO<sub>2</sub>, even at elevated temperatures, while they decompose and form SiC when incident on a bare Si surface. We obtained SiO<sub>2</sub> patterned Si wafers, heated them to around 800°C, and bombarded them with fullerenes. The samples were removed from the UHV chamber, characterized, rinsed in HF and characterized again. The results demonstrated that one can use this method to obtain patterned SiC films [20, 21].

## 1.7 Nanotubes

We have published the *first paper* on STM and AFM of large diameter nanotubes, and the *first paper* on AFM of a single-shell nanotube [22, 23].

## 1.8 Scanning Force Microscopy

Theoretical work on the performance of an AFM using a laser diode interferometer (invented in our lab), and on the tapping mode of operation of an AFM have been performed in our labs [24, 25, 26, 27, 28, 29, 30].

## 1.9 Biology

STM images of cytokeratin and binding IgG antibody have been obtained in collaboration with several departments at the Health Sciences Center [31].

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